ABSORPTION OF ULTRASONIC WAVES IN LiF CRYSTALS

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Absorption of longitudinal waves (800 - 1800 Mc) in the [111] direction of LiF was investigated(1). The authors believe this to be the first such investigation of LiF at these high frequencies. This frequency range was explored for an indication of a dislocation resonant peak(2),(3).

Acoustic waves were induced in the LiF crystal (ends polished flat to a tolerance of 1500 Å and parallel within 4 seconds)(4) by the pulse-echo technique(5),(6). One end of the crystal, bonded to a quartz tranducer was inserted into a reentrant cavity. The rate of decay in the resulting echo train determined the logarithmic decrement. Within experimental error the values of logarithmic decrement in this frequency range were found to lie near the extrapolation of the linear decrement-frequency law found in the 15 - 200 Mc range by Merkulov(7). Merkulov's results (curve 8, Fig. 1) refer to absorption in the [100] direction; the data for an annealed [111] crystal would be expected to be parallel to, and slightly below curve 8. It appears that the logarithmic decrement decreases with annealing in air at 600°C (curve 2, Fig. 1), and increases upon air quenching from 600°C (curve 3, Fig. 1). This effect is in the direction predicted by the expected change in the state of dislocation pinning(3),(8); yet, confirmation of these results would be desirable. General reproducibility of curves 1, 4 and 5 was established through at least four tests at each temperature. It is interesting to note that upon each subsequent reproducibility check at room temperature the base level of the decrement rose slightly. No such trend was observed at 4.2°K. The room temperature data must be considered approximate since it is based on only the first few echoes of the decay pattern. Less than six echoes were obtained at room temperature (Fig. 2a) at the frequencies employed here. At 4.2°K the decrement (corrected for modulation) was low (curve 4, Fig. 1) and up to 60 echoes were noted (Fig. 2b). Results from an unmodulated echo train at 4.2°K are given by curve 5 of Fig. 1. Such an echo train is seen in Fig. 2c.

Clearly, good decrement data are difficult to obtain at these very high frequencies. The modulating effects due to non-parallelism of the end faces and to other causes, and the probable propagation of undesired modes of the wave(9) render the current data and their analysis reliable only to the extent of general qualitative behavior. A crystallographic orientation error of about 2° could be expected from the method of aligning and cutting the crystal(10). This inaccuracy, however, allowed the longitudinal waves in the [111] direction to produce a small resolved shear stress on one or more of the six possible $\{110\}$ $\langle 1\bar{1}0 \rangle$ slip systems(7). In the ideally aligned case (the [111] direction being parallel to the wave vector) such resolution does not occur(7). Furthermore, from the cleavage behavior of LiF, $\{001\}$ $\langle 110 \rangle$ slip could become operative at room temperature(11). Dislocation damping on this system might have occurred, although it is a system presumably active only at temperatures above 400°C(12). Suzuki, et al.(13) have found what they believe to be the dislocation resonant peak in the low megacycle region (far below natural undamped resonance)(3) in the [100] direction, as shown by curves 6 and 7 of Fig. 1. No echoes could be obtained at the frequencies employed in the present study on crystals whose axes were oriented along the [100] or the [110] directions. It is possible that dislocation damping is the cause of the absence of observable echoes in these directions, since the applied stress can be resolved onto four of the six $\{110\}$ $\langle 1\bar{1}0 \rangle$ slip systems.

Tests made at liquid helium temperature revealed the absolute value of the decrement to decrease markedly (curves 4 and 5, Fig. 1) as compared to that at room temperature. Frequency independence of the decrement at 4.2°K has been observed in quartz[5],[6],[9]. In LiF, however, such independence was not found (curves 4 and 5, Fig. 1). The fact that the base level of the decrement changes upon heat treatment in a manner expected from pinning of dislocations[8], suggests a dislocation contribution to the background absorption occurs in the kMc region.

Improved techniques of sample preparation and bonding appear to be required before kMc decrement measurements can be considered quantitatively reliable. Despite the encouraging results noted, conclusive evidence must be based on a pattern of echoes long enough for modulation of the exponential decay to be either observed and corrected, or eliminated. Because of the extreme technological difficulty of attaining the proper conditions for good measurements in the kMc range, the authors feel the present results lack accuracy, yet serve as a basis for further investigation.

Results of this study can be summarized as follows:

(1) the decrement in a [111] oriented LiF crystal appears to have values in the low kMc region equal to those predicted by the extrapolation from the 15 - 200 Mc range;

(2) there may be a frequency-dependent absorption in LiF at 4.2°K;

(3) handling and heat treatment alter the base level of the decrement, suggesting dislocation damping at these high frequencies.

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FIGURE CAPTIONS

Figure 1 Logarithmic Decrement of Longitudinal Waves in LiF Single Crystals

Curve 1-3 Present study - [111] crystal, logarithmic decrement, determined from first few echoes on specimen which had been handled, annealed and quenched, respectively.

4-5 Present study - [111] crystal, logarithmic decrement determined from modulation peaks and exponential decay, respectively, of echo trains obtained at 4.2°K from a specimen which had been handled.

6 Suzuki, et al.[13] - [100] crystal annealed and plastically deformed by compression in the [100] direction.

7 Suzuki, et al.[13] - [100] crystal irradiated with X-rays of about 10^3 R/cm^2.

8 Merkulov[7] - [100] crystal annealed

Figure 2 Oscilloscope Pattern of Echo Trains

2a Room temp., 1240 Mc
1 div. = 2 volts x 5 μsec

2b 4.2°K, 1248 Mc
1 div. = 1 volt x 20 μsec

2c 4.2°K, 1269 Mc
1 div. = 5 volt x 20 μsec

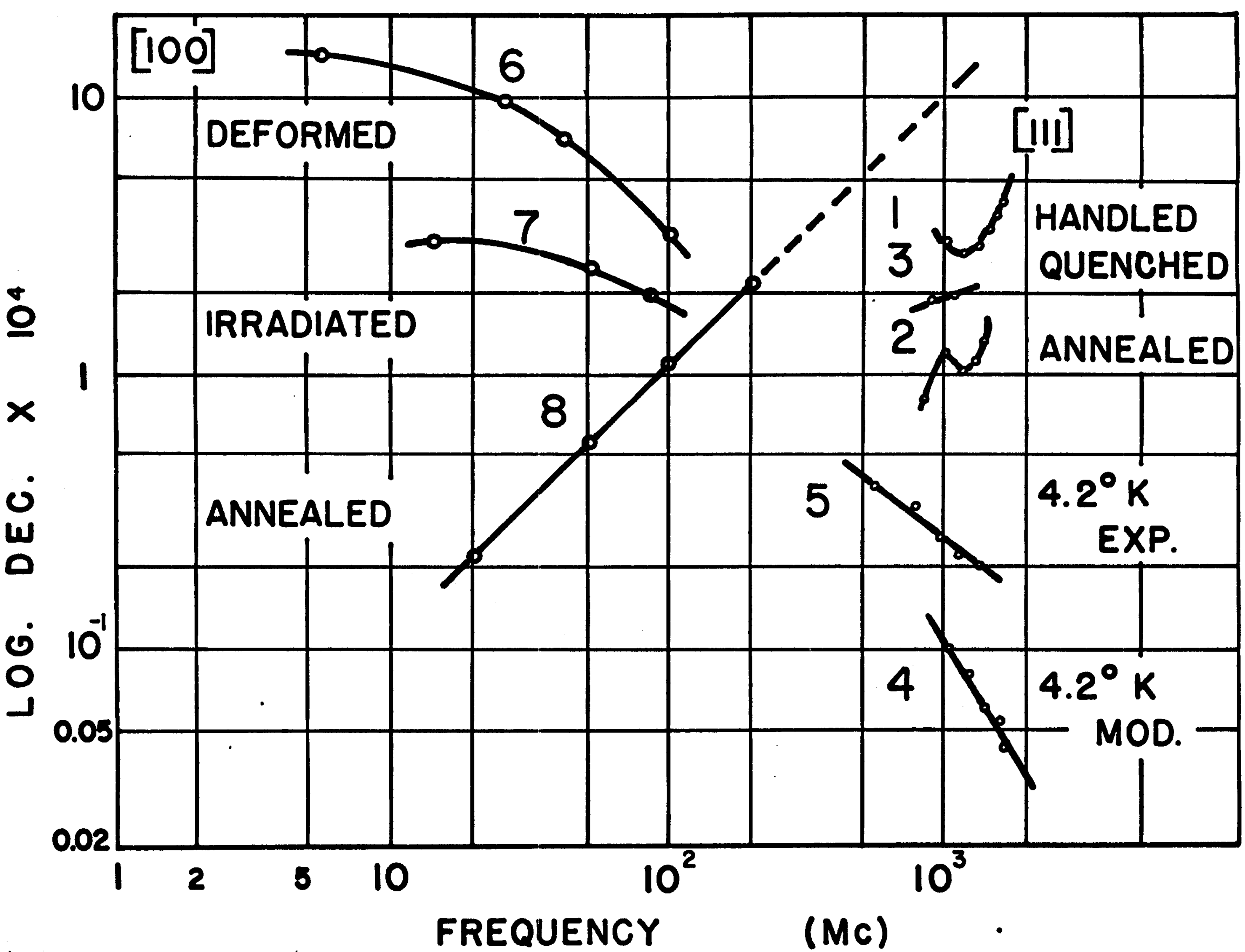
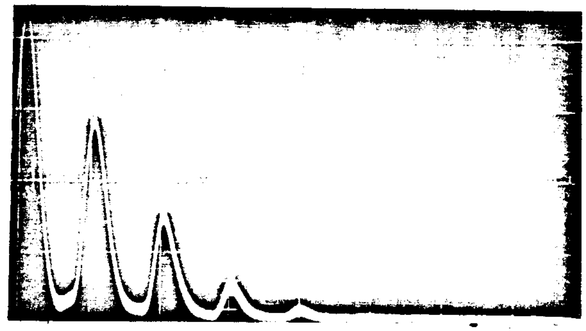
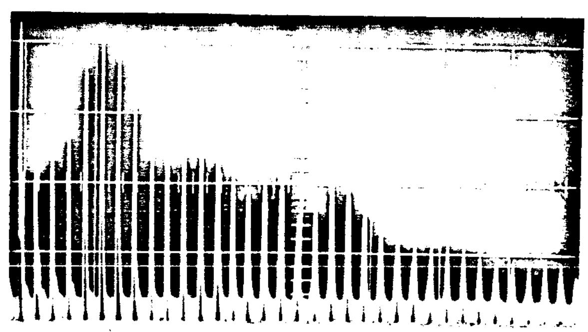


FIGURE I
GOODELL, et al

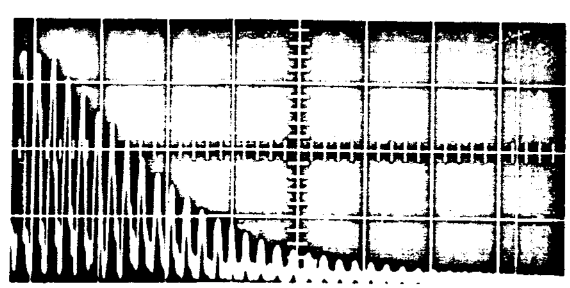
FIGURE 2
ODELL, et al.



2 a



2 b



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